SCIENCE

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SCIENCE AND LIBERAL EDUCATION[1]

SEVERAL years ago a discussion was carried on in one of the London newspapers on that interminable but always interesting question as to what is the best definition of a gentleman. Various answers were suggested by different contributors. Some were in the form of citations from our noblest literature—one, as I recall, was given in the words of St. Paul, another was taken from Shakespeare, a third from Emerson. The one generally acknowledged to be the most effective was, however, phrased in the picturesque vernacular of modern sport. A gentleman, so this answer ran, *is a man who plays the game.*

As this lingers in the memory it brings a growing sense of broader implications. The definition, evidently, only gives a new turn to the old thought that human life is like a great game that man plays with the world. We recall the striking words in which an illustrious master of modern science once brought this thought to bear upon the problem of education:

> The life, the fortune and the happiness of every one of us depend on our knowing something of the rules of a game infinitely more complicated and difficult than chess. It is a game which has been played for untold ages, each man and woman of us being one of the two players in a game of his or her own. The chess-board is the world, the pieces are the phenomena of the universe, the rules of the game are what we call the laws of nature. The player on the other side is hidden from us. We know that his play is always fair, just and patient. But also we know, to our cost, that he never overlooks a mistake or makes the smallest allowance for ignorance. To the man who plays

[1] An academic address given at the opening of Columbia University, September 29, 1915.

well the highest stakes are paid, with that sort of overflowing generosity with which the strong delight in strength. And one who plays ill is checkmated—without haste, but without remorse. My metaphor will remind you of the famous picture in which a great painter has depicted Satan playing at chess with man for his soul. Substitute for the mocking fiend in that picture a calm, strong angel who is playing for love, as we say, and would rather lose than win, and I should accept it as an image of human life. . . .

Well, what I mean by education is learning the rules of this mighty game. In other words, education is the instruction of the intellect in the laws of nature, under which name I include not merely things and their forces but men and their ways, and the fashioning of the affections and the will into an earnest and loving desire to move in harmony with their laws.

And a little farther on it is added that a liberal education should teach us to love all beauty, whether of nature or of art, to hate all vileness, and to respect others as ourselves.

Huxley here formulates his view of education in words that breathe the very essence and spirit of scientific inquiry. The end of education, obviously, is not the mere acquisition of knowledge; it is the attainment of a point of view. And the value of science in this respect, as I think, depends mainly upon the attitude of the scientific investigator towards the study of nature. For he, too, is like a player in a great game. He is quite aware that he can never bring it to a conclusion or sound all of its depths. Nevertheless, he throws himself into it without hesitation, certain of its inexhaustible interest and of possibilities of achievement that are past all reckoning.

I will say but a passing word concerning the work of our professional and technical schools of science. More and more in the future the practical efficiency of our civilization will depend upon that work—in medicine and sanitary science, in agriculture and forestry, in the many branches of engineering—in all those practical disciplines that we speak of as the applied sciences. But civilization does not live by practical efficiency alone, neither is education merely a matter of vocational training. Something larger is here involved. What is the greatest service of science to our intellectual and spiritual life? And this, I take it, is only another way of asking: What is the value of science in general or liberal education?

There are certain obvious aspects of the question that will detain us for a moment only. Science should teach us to keep an open mind; to look facts straight in the face. It should help to deliver us from the deadly vice of thinking we know things of which we are really ignorant. It should lead us to place a higher valuation on observation and experiment than on authority and precedent. We should, of course, acquire some definite information concerning the material world; we should become aware of the fundamental order that is discoverable among natural phenomena; we should gain an intelligent view of man's place in nature. The biologist is apt, perhaps too apt, to emphasize the bearing of his work on problems of human life—psychological, social, political, ethical. No one supposes that all the intricacies of the social organism are at present within the reach of biological searchlights; far from it. Nevertheless, we are ourselves objects in nature and a product of natural processes. No man, I venture to think, can be called liberally educated who has been left indifferent to the issues that are here involved.

But these things, too, let us pass by; they are plain to demonstration. I ask attention to something that is, perhaps, less obvious but to my way of thinking is more important still. The main service of science to our intellectual life is to help preserve us from a certain disorder of the

imagination which I will permit myself to speak of as the malady of Peter Bell. I make no attempt to disguise the fact that Peter Bell and his celebrated primrose have begun to show the ravages of time. Even so, I suspect that science will not with impunity lay her desecrating hand upon Wordsworth's parable. And yet that perennial primrose by a river's brim, which through every changeful year

> A yellow primrose was to him
> And it was nothing more—

that weather-beaten botanical specimen, I say, symbolizes a kind of mental myopia with which the man of science feels himself to be as much concerned as the poet. Science has a very definite part to play in the treatment of this insidious ailment. It should adjust our vision to the larger meanings of things in the material world. And by this I mean to say *that science should develop—and it should discipline—the constructive imagination.*

This thought, I must admit, is very far from novel; to some, nevertheless, it may seem to be a rather quixotic notion. Let me then briefly set forth some of the grounds that lead me to adopt it. I might cite here Tyndall's historic address on the scientific use of the imagination—one with which every student of science should be familar. But lest I be accused of calling upon a prejudiced witness, I will turn to the dry light of legal authority, recalling words that were written long ago by Sir Frederick Pollock:

> It is an open secret to the few, but a mystery and a stumbling block to the many, that Science and Poetry are own sisters; insomuch that in those branches of scientific inquiry which are most abstract, most formal, and most remote from the grasp of the ordinary sensible imagination, a higher power of imagination akin to the creative insight of the poet is most needed and most fruitful of lasting work.

This was an eminently sound and upright judgment, yet the mystery seems not wholly to have been dispelled. Even now we not infrequently are asked: Is not science a negation of all that is poetic or imaginative? Is it not concerned with hard facts, with exact weights and measures, with sharply defined and rigid concepts, with the iron rule of "blind force" and "inexorable law" in nature? Well, this view of science is known esoterically, in the seclusion of the laboratory, as the Great Myth. We can make some use of it, to be sure, as a kind of polite fiction with which to introduce the neophyte to the methods of science. We glibly insist that the student must above all things learn to observe, measure and weigh with "irreproachable accuracy." With this demand he struggles valiantly but in vain; meanwhile, however, the fundamental truth begins to dawn upon him that nobody is able with perfect accuracy to observe, measure or weigh anything. We are always in error, more or less. Science—and here I mean the sciences of observation and experiment—has not the smallest hope of attaining to absolute precision. She is quite content to determine the probable limits of error!

The fundamental concepts of science are in no better case than her weights and measures. They have no finality. They are but a means of advancing knowledge; they move as science moves. But yesterday we were told that atoms are infinitesimal, indivisible, ultimate. To-day we are holding our breath as we watch the physicist soaring upon the wings of imagination inside the atom in pursuit of still more infinitesimal, still more indivisible, still more ultimate electrons which, like the stars of heaven, are rushing through the tremendous solitudes of intra-atomic space! Tomorrow, no doubt, the scene of these daring flights will be shifted to the nebulous and illimitable regions that lie still unex-

plored within the electron. What would the illustrious Dalton think of all this could he contemplate to-day the fate of his epoch-making theory after a century of scientific progress? We may imagine him saying to himself: "Well, Well! the concept of the atom seems to have made some progress since my time; evidently it still is moving onwards. And yet, the flourishing state of latter-day physics and chemistry gives me an impression that the atomic theory, with all its faults, has played a certain useful part in the advancement of knowledge."

Surely then, it may be said, we can make a final stand upon the laws of nature. Are not these immutable and eternal? Do they not govern the world as overruling necessities? Science and philosophy alike reply: Who knows? The laws of nature are known to us only as observed uniformities or harmonies of action. We can not affirm with certainty that any one of them—not the law of the conservation of energy, not even the law of gravitation—is fixed or universal. No particular law of nature—and here I employ the words of a great master of mathematical physics—will ever be more than approximate and probable, nor can we state it completely. But this, says some one, is a confession of the fundamental bankruptcy of science! No; our cynical friend goes too fast; his remark betrays a failure to comprehend either the aims of modern science or the nature of scientific progress. We have no notion that our plummets will so easily touch the bottom of nature; we do not hope to divine the final essence of things. And were it otherwise, were it possible for our knowledge of nature to be frozen, once for all, into a hard, mechanical and completed system, the most potent spell of science would be broken. A deep-seated instinct of our human nature here asserts itself; one that has found expression in the philosophy and poetry of every age. It is a saying of Confucius that they who know the truth are not equal to those who love it. Which one of us, were we forced to choose, would not in the end make the famous choice of Lessing:

> If God held in his right hand all truth, and in his left nothing but the ever-ardent desire for truth, even with the condition that I should err forever, and bade me choose, I would bow down to his left hand, saying, "Father, give me this; pure truth can be but for Thee alone."

Such a choice, however, is not very likely to fall to our lot; nor does the poet here suggest the actual attitude of science. Malbranche is nearer to it in that delightful remark that if he held truth captive in his hand he would open his hand and let it fly, in order that he might pursue and capture it again. Here we sense the spirit of the sportsman. With somewhat of the same spirit, beyond a doubt, does the discoverer play his small part in the mighty game of science.

And this brings us to the vital point. Not merely in a spirit of sportsmanship does science play her game; she also strives to realize an ideal, one that is very plain and simple. And this ideal is, in a single word, *progress*. Not to solve the ultimate riddles of the universe, if such there be, not to attain to absolute truth, but to advance knowledge—such is the aim of science. When once we have felt the full force of this, all is clear. Then we see that although the laws of nature can be formulated in only a tentative and provisional way, they are not for this reason less valuable to us; they are more so. Then we grasp Huxley's full meaning when he calls these laws the rules of the game we play. We can not with certainty ascribe to them any quality of necessary or inflexible truth. Our knowledge of nature is of inestimable value to us; but it is nowhere absolute or final. The profound

significance of what we call natural laws lies in the fact that they tersely sum up our experience of the world at any given moment; and, above all, they endow us with a gift of prophecy that leads us on to new advances. Just here we are in sight of what is most vital, characteristic and hopeful in the spirit of modern science; and here, too, the all-important rôle of the scientific imagination first begins really to impress us.

Our assured knowledge of nature is gained little by little, through the slow and cautious processes of observation, experiment and reason; but far different from these is the motive power of science. In every field the great discoverers have been seers, men of imaginative vision, carried onwards by a swift intuition that runs far in advance of solid fact or rigorous logic and ranges freely to and fro in undiscovered realms beyond them. And this is a true creative process, one that is singularly like what we call the inspiration of the painter or the poet. It often thrills us in the same way. Such a work of the imagination was Michael Faraday's wonderful anticipation of the electro-magnetic theory of light. Such was Charles Darwin's conception of natural selection which, as he himself has related, suddenly flashed upon his mind as he was reading the famous book of Malthus. Such, again, were the dreams that led Louis Pasteur and his followers, step by step, from the phenomena of fermentation and putrefaction to that most beneficent and practical achievement of our civilization—the germ theory of disease. At every point the material world overflows with half-revealed meanings about which science is forever weaving her imaginative fabrics; and at their best these have all the freedom, boldness and beauty of true works of art. One conspicuous trait, indeed, distinguishes the man of science—his incorrigible, almost automatic insistence upon verification. For no one better knows that the children of his imagination will live only in so far as they take on the living flesh and blood of reality in the appeal to nature. Not many of them survive the ordeal; yet they are the pioneers of progress, and the real conquerors of the world. Our own alma mater has placed above the portal of one of her great halls of science the words: "*Speak to the earth and it shall teach thee.*" Beside them we might fittingly inscribe that other Scriptural admonition: *Prove all things; hold fast that which is good.*

I say once more, then, that the development and discipline of the imagination is the best gift of science to our intellectual life, and hence to liberal education. Permit me also to suggest that there is no royal road, no pedagogical short-cut, that will lead us to it. Lectures and text-books on science are, I suppose, a necessary part of the apparatus of educational nutrition. Not by them, however, but by the actual phenomena of nature is the scientific imagination first awakened to its real life. Our laboratories of science have their shortcomings; in them, nevertheless, such as they are, the fruitful and abiding lessons of science are learned. It must not be imagined that the student has no other occupation than to disport himself at ease in that legendary realm of popular fancy known as the "fairyland of science." The prosaic but wholesome truth is that most of us are kept too busy digging out facts at lower levels to have much opportunity to breathe the atmosphere of the upper altitudes. But if the learner can not be taken up straightway to the highest mountain peaks, he may at least be enabled now and then to catch glimpses of them from the quarries in the foot-hills where most of us are toiling. And such moments of larger

vision repay with overflowing measure all the labor they have cost, for it is then that the miracle is wrought and the eyes of Peter Bell are opened.

Permit me one more word. Science lays her spell upon us because she lives and moves. It ought to be clear that the advancement of knowledge is not less vital to the educational interests of the university than are its conservation and dissemination. Are we quite sure of ourselves in this regard? We have heard of late an intimation that the universities have not been so much leaders of progress as "depositories of stationary thought." Well, depositories of stationary thought the universities indubitably have been, like the monasteries that they succeeded as centers of learning; and they have thus served as the guardians of a treasure that is beyond all price. But this is only half the truth; for it has long been one of our most cherished ideals that universities should also be the natural homes of original discovery and productive scholarship. The real universities—and I believe that our own is one of them—have demonstrated by their example that the atmosphere which these things create make teaching live and move. But even as we are insisting upon this we find ourselves wondering how our ideal is likely to fare hereafter in the continual expansion of modern universities and the multiplicity of new demands upon their teaching resources. Our pedagogical and executive machinery is admirably organized. It has developed a high degree of efficiency. Will it be efficient enough in the future to maintain an atmosphere in which scientific research and creative scholarship may freely breathe? It is easier to ask hard questions than to answer them. This one, nevertheless, we shall not escape; for the day is coming when the leadership of the universities in intellectual progress will depend on the reply that we and those after us shall make; and not our words, but our deeds will speak for us.

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PLAIN WRITING[1]

Two years ago I spoke to the American Mining Congress on the subject "Plain Talk"—both preaching the use of direct statement and trying to practise what I preached. Of late my thoughts have turned more and more to the need of the use of popular language in stating technical results; hence this afternoon I venture to discuss plain writing from the standpoint of a government scientist. For twenty-odd years my association with scientists has been fairly intimate, and though I may not qualify in plain writing myself, I can claim large acquaintance with both the written and the printed page whose meaning is far from plain.

At its best, science is simple; for science is not much more than arranging facts so as to set forth the truth. Scientific thought is exact and direct, and scientific writing must therefore be accurate and to the point. The scientist should think directly and with the precision of one of the instruments of his trade, and above all his language must present that thought exactly.

In scientific writing this need of exact statement has led to the use of special terms, words that keep their razor-edge because used only for hair-splitting distinctions. In a certain degree this adoption of words not commonly used is unavoidable and therefore defensible. Yet the practise is carried to an extreme and far too often the result is a highly specialized language so distantly related to our mother tongue that as a preliminary qualification the writer has to pass a civil-service examination and the reader usually finds himself "shut out" and facing a "no admittance" sign unless he happens to possess the degree of Doctor of

[1] Meeting of American Mining Congress, San Francisco, September 13, 1915.